# Acquired Limb Deficiencies. 4. Troubleshooting

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This self-directed learning module offers practical analyses of and solutions for common clinical problems of amputees. It is part of the chapter on acquired limb deficiencies in the Self-Directed Physiatric Education Program for practitioners and trainees in physical medicine and rehabilitation. The information presented here has been designed to be useful also to other interested professionals, including prosthetists, physical therapists, occupational therapists, and nurses. Topics covered include the management of typical obstacles encountered in upper limb amputees, and the diagnosis and treatment of phantom and residual limb pain. Diagnostic and treatment approaches to skin breakdown in the transtibial amputee and to knee instability in the transfemoral amputee are also presented.

**Overall Article Objective:** To analyze common clinical problems of amputees.

**Key Words:** Amputation; Phantom limb; Pain; Prostheses and implants; Skin care; Rehabilitation.

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### 4.1 Objective: To identify and overcome common obstacles associated with body-powered and upper limb prostheses.

The early goals in rehabilitation of the upper limb amputee include stabilization of the residual limb volume and shape and fabrication of the prosthesis. The new amputee may encounter problems of pain, wound healing, body image, and cosmesis. After the prosthesis has been fabricated and fitted, the amputee enters the postacute stage in which a new set of problems can interfere with prosthetic use. Skin irritation or breakdown and difficulty in operating the prostheses may be due to poor fit, inappropriate cable and strap postition of function, or component failure.

## SOCKET PROBLEMS AND SOLUTIONS

A poorly fitting upper limb prosthetic socket can cause local irritation or discomfort. Bony prominences (eg, the radial and ulnar styloid processes, the humeral condyles) are particularly vulnerable. For instance, if the proximal trim line of a transradial socket is too short or is not flared away from the ulna, local discomfort over the ulna results. If the proximal trim lines are too distal, the socket will slide on the residual limb and create irritation. Skillful reshaping of the socket's inner wall usually provides relief. Socket modification must redistribute pressure while maintaining a secure fit that can resist slippage and rotatory forces. Adding padding or other materials in the area of irritation is not usually indicated because the padding often creates additional pressure. Lining the socket with silicone can reduce friction if shear is the culprit. Ultimately, if a socket cannot be adequately reshaped to relieve areas of excessive pressure, socket replacement should be considered.

Patients with very short transradial amputations can be difficult to fit because the proximal trim lines must be placed near the antecubital fossa to offer effective suspension. This can interfere with elbow flexion and can cause soft tissue impingement and pain. When limited range of motion interferes with prosthetic function, a step-up hinge system with a split socket will increase available flexion.[1] However, such a system doubles the amount of force the amputee must generate to flex the elbow and forearm. Discomfort may occur in the medial or lateral forearm, which can be attenuated by using a split-cable system.[2] A forearm lift assist can also aid elbow flexion for those amputees who lack strength or endurance. This device is attached medially to the socket and counterbalances the weight of the forearm. In some cases, a second forearm lift assist is indicated, particularly for transhumeral amputees. If these efforts fail, the transradial amputee may be successfully fitted as a transhumeral amputee. This is often true for the individual whose residual forearm disappears into the antecubital fossa with elbow flexion.

Suction suspension and other self-suspension systems depend on an intimate interface between the residuum and the socket. Volumetric or geometric fluctuations of the residual limb adversely affect fit. This is especially true for self-suspending systems, which are found more commonly in myoelectric systems. If increased residual limb volume is due to disuse, such as occurs when the prosthesis is not used for a period of days, an elasticized stump shrinker or similar device can be used to reduce the limb size. The use of elastic bandages (ie, Ace wraps) requires that the patient employ the correct wrapping technique to avoid tissue folds or creases and proximal constriction, which can result in vascular congestion. Because elasticized stump shrinkers are easier to don, they encourage compliance. Once the limb volume has restabilized, prosthetic wear can be resumed.

A weight change of 5 to 10lb can result in a change of residual limb volume and alter socket fit. Significant change in the volume or shape of the residual limb should alert the clinician to screen for systemic disease (ie, a neoplasm in the face of unexpected weight loss). Although loss of volume can often be corrected by adding stump socks or by padding or lining the socket, significant weight gain typically necessitates fabrication of a new socket.

The choke syndrome (proximal soft tissue constriction leading to vascular congestion) may occur with suction sockets or self-suspending systems. Relieving the proximal socket to allow vascular return, providing auxiliary suspension to decrease the vertical pull on the residual limb, and improving the inti-

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macy of the socket-limb interface are approaches to correct this problem. In the transhumeral amputee, adding a supra-acromial strap (attached on the harness in an anteroposterior direction) often resolves this problem by minimizing the loss of distal contact from a vertically migrating socket responding to the force of gravity.

## PROBLEMS AND SOLUTIONS IN OPERATING THE PROSTHESIS

Successful use of a body-powered or a hybrid system requires a certain amount of strength and range of motion. Scapular excursion, chest expansion, and shoulder and elbow motion can all be used to provide cable tension. Physical or occupational therapy may be indicated if the patient lacks the necessary power or limb mobility to operate these types of prostheses.

If an amputee with adequate strength and range of motion is having difficulty operating the prosthesis, an obvious first step is to evaluate the condition of the terminal device and mechanical joints (eg, elbow and wrist unit). The cable, the housing, and the fittings should be inspected. The most common problem is with the housing binding the cable movement. Mechanical wrist units with friction control are adjustable. The amount of resistance to supination and pronation can be adjusted with an Allen wrench. If the nylon bushings are sufficiently worn or damaged, replacement is warranted. Heavy-duty use may demand greater torque resistance of a wrist unit to lock the terminal device in a set amount of pronation or supination. A quick-change wrist unit is preferred for these users.

## HARNESSES AND CABLES

The fit of the harness is directly related to the efficiency and operation of the prosthesis. The figure-of-8 harness is the configuration most commonly used after transradial and transhumeral amputations.[3] The harness should fit snugly, flat against the back, without compromising the neurovascular bundle of the sound arm (brachial plexopathy, mononeuropathy, or vascular occlusion may result). The axilla loop anchors the control straps of the prosthesis; it too should fit securely. This becomes increasingly important with shorter residual limbs. Irritation within the axilla can be caused by friction from the axilla loop against bare skin. A T-shirt or some other absorbent garment worn under the harness is recommended. Covering the axilla loop with lamb's wool or other soft material, or employing a wider strap, will also reduce chafing. If the control attachment strap of the harness is resting too proximally on the thorax, the amputee may not be able to achieve sufficient cable excursion to operate the prosthesis. This strap should rest midway between the inferior and the superior borders of the scapula, with the intersection of the harness straps lateral to the spinous processes toward the sound side. When the control strap is located too far distally, the amputee must recruit a more forceful shoulder flexion motion to operate the mechanical elbow or terminal device. Likewise, the efficiency of the harness and control system may be hampered by too proximal positioning of the posterior intersection of the harness straps (ie, at or above the C7 spinous process). If this is the case, refitting the harness or adding a cross back strap will keep the harness in position and maintain its efficiency and comfort.

The anterior strap prevents displacement of the socket during loading. If displacement is still present after the harness and socket have been examined and adjusted, the patient may be better served with a "heavy duty" or shoulder-saddle design. The shoulder-saddle design can be modified with a Bowden cable and housing placed on the anterior and posterior aspect of the saddle. This cable can operate more freely and prevent the saddle harness from becoming displaced with vertical loading.

When the anterior strap is torn, stretched out, or not placed properly, the amputee will experience excessive rotation. If the prosthesis has flexible elbow hinges, these too can be stretched out, allowing the socket to slide on the residual limb. The hinges may need to be replaced or reattached more distally on the socket.

Some patients have difficulty tolerating harnesses. Adding a cross back strap or O rings or changing the type of harness may improve comfort. Other options to improve comfort include sleeve suspension, roll-on liners with locking mechanisms, and sockets with flexible liners. A transradial amputee may benefit from a Muenster socket or sleeve suspension (eg, a neoprene sleeve) with a figure-of-9 harness. The figure-of-9 harness, however, is not a good choice for the amputee who does a significant amount of lifting. Others benefit from myoelectric or hybrid prosthetic systems, which require less harnessing. Suction suspension can also reduce harnessing needs, but requires close monitoring to maintain an effective fit. Roll-on liners can cause excessive perspiration. If this problem persists, topical antiperspirants are usually indicated. Resistant perspiration may be treated with oral medications or electrolysis. Residual limbs with significant tissue deficits or split-thickness skin grafts are typically not good candidates for suction suspension systems. Roll-on liners are often helpful in these cases.

### 4.2 Objective: To discuss medicines and physical modalities in the treatment of phantom limb pain.

The first step in treating phantom limb pain (PLP) is accurate diagnosis. The cardinal feature of PLP is painful sensation perceived in a body part that has been lost or never developed. This should be distinguished from phantom sensation, a nonpainful awareness (ie, proprioception, pressure, wetness, itching, tickle) of the absent limb, and from residual limb pain. Phantom sensation is usually not treated pharmacologically. Residual limb pain can be due to multiple causes, including infection, vascular insufficiency, necrosis, prosthetic fit, bone spurs, and neuroma formation.[4]

Optimal treatment of pain arising from an amputation begins in the preoperative and perioperative periods. Although not definitively linked with better outcomes, compassionate care suggests counseling to help prepare the prospective amputee for limb loss and aggressive treatment of pain. Compression, early mobilization, and active desensitization of the residual limb should decrease edema, and pain, and help the new amputee patient regain a sense of personal control over his/her body. Actual use of a prosthesis has been associated with decreased PLP.[5]

## PREOPERATIVE EPIDURAL TREATMENT

Several early studies have shown that the use of an epidural block preceding amputation may diminish or obliterated the occurrence of PLP.[6-8] This treatment was supported by the observation that limb pain prior to surgery was correlated with the incidence of residual limb pain and PLP after surgery.[9] Despite encouraging results, these initial studies were limited by small sample sizes, insufficient randomization, and nonblinded assessment of treatment effects.[10] In a well-constructed placebo-controlled trial of peroperative epidural treatment, 60 patients scheduled for lower limb amputation were randomized to receive either a continuous infusion of bupivacaine (.25%, 4–7mL/hr) and morphine (.16–.28mg/hr) or an infusion of epidural saline and paracetamol 4 times daily and morphine 4

to 6 times daily.[10] The treatment regimens started 18 hours before surgery, and the infusions were continued during surgery. No statistical differences were found between the treatment and control groups in regard to phantom pain at 1 week and 3, 6, or 12 months. It is unlikely that higher doses of medication would have been more effective, because the patients were rendered pain free by the test doses. It is possible that a longer period of pretreatment would have been effective because the earlier trials treated patients from 24 hours to 3 days preoperatively.

## PERIPHERAL STIMULATION

Peripheral stimulation in the form of transcutaneous electrical nerve stimulation (TENS), vibration, and acupuncture have all been used with benefit in PLP. Winnem and Amundsen[11] treated 11 amputee patients with disabling PLP with TENS for 2 15-minute sessions twice per day for 5 days. TENS treatment was initiated at high frequency (100Hz) in the residual limb, but was switched to low frequency (2Hz) if high-frequency stimulation failed to effect relief. If TENS remained ineffective, the procedure was repeated in the intact limb "segmentally to the area of pain." Two patients achieved complete relief, and 5 others experienced "very definite improvement." Responders experienced 50% reduction in consumption of analgesics. Follow-up ranged from 3 to 12 months. A study of the effects of TENS on healing the residuum and on PLP in 51 persons about to undergo amputation was performed by Finsen et al.[12] This trial compared sham TENS alone, sham TENS plus chlorpromazine, and genuine low-frequency TENS (7 pulses twice per second, 100Hz, 90$\mu$s duration). Healing rates were higher in the genuine TENS group. At 4 weeks, there was no difference in PLP. At 16 weeks, none of the patients receiving real TENS had PLP, whereas 4 of 11 receiving sham TENS plus the drug and 7 of 12 receiving sham TENS alone complained of PLP. These group differences disappeared by the end of 1 year, at which point PLP was judged to be "slight and occasional" in those affected. Auricular TENS has also led to modest improvement in chronic PLP in 11 amputee patients.[13] Literature supporting the use of acupuncture and massage is limited by lack of statistical analysis and by nonrandomization.[14,15]

## PROSTHETIC USE

Use of a Sauerbach prosthesis and myoelectric prostheses has reduced PLP in upper limb amputee patients.[5,16] Weiss et al[5] studied 9 patients who had received a Sauerbach prosthesis and compared them with 12 patients using a cosmetic prosthesis. The Sauerbach prosthesis surgically connects an upper limb muscle directly to the mechanism of the prosthesis. Those with the Sauerbach prosthesis experienced a significant drop in PLP compared with those with cosmetic prostheses. Limitations of this study include the nonrandomization of patients, the retrospective nature of the study, and the fact that the Sauerbach users were patients of one of the investigators. Lotze et al[16] studied 14 unilateral upper limb amputee patients and found that the 5 using myoelectric prostheses had no PLP compared with the 9 who either did not wear a prosthesis or used a cosmetic prosthesis and whose PLP was rated as a mean of 2.33 on a 6-point scale. Cortical reorganization was investigated with functional magnetic resonance imaging while the subjects performed a lip motor task. Those free of PLP showed hemispheric symmetry in lip representation, whereas in those with PLP the lip area was displaced toward the hand area in the hemisphere contralateral to the amputated hand. Lotze suggested that use of the prosthesis prevented or blunted maladaptive reorganization responsible for PLP. Well-controlled, randomized trials must be performed to substantiate such claims.

## PRINCIPLES FOR EFFECTIVE DOSING OF MEDICATIONS IN PLP

Adherence to established principles of pain management will yield the best chance of success in PLP.

1. The temptation to start more than 1 pharmacologic agent at a time should be avoided. Although combinations of medications may ultimately be necessary, determining which medicine is responsible for an unpleasant side-effect is often impossible if more than 1 medicine is started at a time. Further, the patient may reject both medications because of an unpleasant interaction, when either alone might have been sufficient.
2. The regimen should begin with a modest dose; the efficacy and the incidence of unwanted side-effects should be monitored. If the initial dose is too great, the patient may reject the medication because of intolerable side-effects. Once this occurs, the practitioner may have to overcome considerable skepticism when trying to reintroduce the medicine at a lesser dose. An example is a patient who is started on 25 to 50mg of amitriptyline, only to be overcome by sedation, dry mouth, or urinary hesitancy. Such patients may become convinced that amitriptyline does not work and begin to question the competence of the physician. As a result, the physician may have difficulty persuading the patient to try the medicine again at a dose of 10mg, which is often well tolerated and effective.
3. The dose should be increased in a gentle and deliberate manner until either the medication is completely effective or the benefits of treatment no longer outweigh the unpleasant side-effects. At a certain point, the dose may have to be reduced to reach the most favorable balance between desired and undesired effects. If the side-effects are intolerable at the lowest dose or the medicine offers no significant treatment effect, discontinuation of the medication and initiation of an alternative are appropriate. If the best balance between effect and side-effect is reached, but relief of symptoms is not satisfactory, the first medicine may be maintained while a second is introduced. When additional medications are considered, agents with different mechanisms of action are usually preferred to agents with mechanisms similar to those medications that have already been tried.
4. Once optimal control has been obtained, simplification of multi-drug regimens should be attempted. Starting with 1 medication, the physician should reduce the doses of each medication in a stepwise manner, as tolerated, until the minimal effective regimen has been established. This will reduce costs and chances of complications. A simpler regimen should also improve compliance.

## PHARMACOLOGIC AGENTS FOR THE TREATMENT OF PLP

The literature on the definitive pharmacologic treatment of PLP is sparse, perhaps because PLP is relatively rare in the general population. Therefore, clinicians must adapt agents and strategies that are used to treat other neuropathic disorders.

Amitriptyline and gabapentin can be considered the first-line agents in the pharmacologic treatment of PLP. *Amitriptyline* is a tricyclic antidepressant with noradrenergic, serotoninergic, anticholinergic, and antihistaminergic properties. It is reasonably well established and effective in treating neuropathic pain

and fibromyalgia, and it is relatively inexpensive. Its tendency to cause somnolence can be used to help restore sleep, which is often disrupted in pain syndromes. Amitriptyline also may help alleviate the commonly associated depression, although doses to treat depression are typically higher. Alternatives to amitriptyline include other tricyclics such as nortriptyline and the anticonvulsant carbamazepine.[17] *Gabapentin* is often effective against pain of a neuropathic origin and has a modest side effect profile.[18] It is, however, relatively expensive.

Other agents are used less commonly. *Capsaicin,* a natural extract of chili peppers, when applied topically causes the release of substance P and other neuropeptides from the terminals of slow-conducting unmyelinated C fibers. With repeated dosing, substance P becomes depleted. Capsaicin has been used effectively to treat residual limb pain (as opposed to PLP) in 3 patients, and it is free of systemic side-effects; however, it can cause unpleasant burning discomfort where topically applied.[19] *Calcitonin* is a peptide hormone involved in the regulation of calcium homeostasis that is secreted by the perifollicular cells of the thyroid gland. The mechanism of calcitonin's antinociceptive properties is unknown, although an increase in beta endorphins and stimulation of serotoninergic neurons may be involved.[20] Calcitonin has been effective in PLP in 2 trials.[21,22] Adverse effects include nausea, vomiting, and allergic reactions. *Mexiletine* is a class 1B antidysrhythmic agent that has also found use in neuropathic pain syndromes (eg, painful diabetic neuropathy). Its mechanism of action is believed related to its effect on sodium-potassium channels, resulting in less peripheral nerve excitability. Mexiletine has been effective in an open-label trial of 31 amputee patients with PLP.[23] The risk of sudden death in patients taking this medication for dysrhythmias suggests a cautious approach to its use.

*Carbamazepine* is an anticonvulsant with a ring structure that is similar to that of the tricyclic antidepressants. Its analgesic properties are thought to be due to its sodium channel-blocking capacity and consequent membrane-stabilizing effect. Carbamazepine has reportedly been effective in the treatment of lancinating PLP in 6 amputee patients.[24,25] Hematologic parameters must be monitored because blood dyscrasias are a possible side-effect.

The application of beta blockers in phantom pain is unusual, although they are occasionally used in neuropathic pain conditions such as reflex sympathetic dystrophy and complex regional pain syndrome. Complete relief of PLP has been reported in three amputee patients who received *propranolol* for angina.[26,27] Two additional persons responded to propranolol, and another to *metoprolol* in a separate study.[28]

*Clonazepam* is a benzodiazepine that was initially used to treat petit mal and myoclonic seizures. Benzodiazepines enhance the action of gamma-aminobutyric acid within the central nervous system.[27] Clonazepam increases serotonin synthesis and serotonin concentrations at synaptic receptor sites. It provided relief from shooting and shocking PLP refractory to "various narcotic and non-narcotic analgesics" in a case report of 2 persons with hip disarticulation.[29]

### 4.3 Objective: To describe the causes and management of transtibial residual limb skin breakdown.

The first task of the practitioner is to determine the cause of the lesion(s). Skin problems are most commonly due to prosthetic causes (ie, a reaction to friction, pressure, shear, undue suction or choking due a poorly fitting socket, or malalignment of the prosthesis). They can also be caused by a dermatologic reaction to the materials of the interface. Less commonly, skin lesions can be due to dermatologic or vascular conditions unrelated to the prosthesis. To diagnose and treat lesions of the residual limb, the clinician must examine the prosthetic history along with a medical history and review of systems. The clinician should determine when the problem was first noted, any aggravating and relieving factors, whether the reaction is related to prosthetic use, the amount of time spent in the prosthesis, whether there have been any changes in the prosthetic prescription (ie, change of shoes to a set with a different heel height), or changes in kind or level of activity.

The physical examination often begins before the patient is aware that it has commenced. The patient is observed as he/she walks into the room. This often provides the truest glimpse of the patient's actual gait pattern. Later in the examination, when patients know they are being observed, they may consciously or unconsciously minimize or compensate for deviations to please the examiner, or they may exaggerate deviations to call attention to the perceived seriousness of the problem. Patients should also be watched carefully while they don and doff their prosthesis. Errors in technique may be at the root of their problem.

When the residual limb has been exposed, the color, shape, size, texture, and distribution of the lesions should be noted, along with the condition and shape of the residual limb. Scars should be noted. Palpation of the limb will disclose the extent of tenderness, the presence and quality of edema, and the amount of muscle bulk and atrophy. Palpation can also reveal areas of tissue adherence to the underlying bone. These areas are at greater risk of injury during the normal shearing movements of the socket on the limb during ambulation.

A variety of lesions may be seen and can give clues as to the duration and nature of the problem. Reactive hyperemia is among the first reactions to excessive shear or pressure. In the presence of moisture, this may progress to maceration.[30] Blisters represent a more serious mismatch between the user's skin and the shear and pressure of the environment. Further progression can lead to frank ulceration. Tissue can also proliferate in response to shear or pressure. Lichenification (thickened, leathery skin) can form at areas where repetitive stresses exceed skin tolerance. Callosities usually form over bony prominences. Verrucose hyperplasia, a warty condition of the distal limb, can form, especially in the setting of proximal constriction, vascular insufficiency, and excessive distal suction.

The treatment for open wounds is wound care, cessation from wearing the prosthesis, and appropriate prosthetic modification. The patient should not use the prosthesis until the wound has healed except in some instances of minor ulceration or abrasion where the wound can be covered with a padded occlusive dressing such as DuoDERM[a] and prosthetic use can be resumed immediately after modification. For closed wounds, prosthetic modification is often sufficient. Modification can be as simple as adding socks or changing alignment, or it may demand liner or socket modification, replacement of the socket or other components, or a totally new prosthesis. In many settings, these decisions are best left to the prosthetist. However, even better results are likely if the physician can add his/her insight based on medical knowledge and a sound understanding of the biomechanical interplay between user and prosthesis.

The patient should be observed in the prosthesis while standing (static analysis) and during ambulation (dynamic analysis). Standard alignment of the patellar tendon–bearing prosthesis is designed to maintain balance, advance the prosthetic foot in the normal line of progression, and preserve comfort and integrity of the skin by preferentially loading the soft tissues and lessening the load over bony prominences. For an uncomplicated transtibial amputee with no significant knee contractures, standard alignment has been well defined. Medial tibial plateau-to-

floor length and pelvis-to-floor length should be equal to those dimensions in the intact lower limb. The socket is prepositioned in 5° of adduction and 5° to 10° of anterior tilt.[31] The anterior tilt allows loading of the soft tissues of the anterior surface of the residual limb. The foot is slightly inset relative to the socket. The patellar tendon bar is located halfway between the tibial tubercle and the distal end of the patella. The posterior brim of the socket should end about an inch below the patellar tendon bar, with reliefs made for the hamstring tendons. The socket and liner should fit intimately, and the socket should have contours that spare the bony prominences. In normal prosthetic walking, only a miniscule amount of pistoning should be evident.

Deviation from proper alignment can cause excessive pressure and shear in predictable patterns. The anterior distal area overlying the end of the tibia is especially vulnerable because of its paucity of soft tissue coverage and its position at the end of the tibial lever arm. There are 4 common socket-related problems that expose the distal tibia to elevated forces that may lead to breakdown: (1) a socket that is too large, (2) a socket that is too broad in the anteroposterior plane ("bell clapper" effect), (3) insufficient socket flexion or anterior tilt of the socket on the pylon, and (4) excessive anterior tilt of the socket on the pylon. If the socket is too large, the residual limb can "bottom out." The patellar tendon bar will migrate proximally and approach or cover the patella in standing. When the socket is removed, erythema may be evident where the patella has met the patella tendon bar. The hamstring tendons may also be pinched. The use of putty, powder, and pressure transducers can all give valuable information about the amount and extent of contact between the residuum and the socket.

Insufficient anterior tilt can increase distal end bearing because the anterior soft tissues are not adequately loaded. The lack of anterior tilt becomes evident when the prosthesis is removed and is observed upright with the foot resting on a flat surface. Too great an angle of anterior tilt places the ground reaction force far posterior to the knee axis at heel strike. This causes knee flexion moment that must be countered by forceful contraction of the quadriceps to prevent further knee instability. The distal tibia must ultimately absorb the torque of the rotating socket. Other causes of a premature and increased knee flexion moment at initial contact include excessive heel height, excessive length of the heel lever arm, and excessive dorsiflexion of the foot. No matter which of these is the culprit, the result is the same: increased anterior distal and posterior proximal pressure.

A foot that is inset too far relative to the socket will place the ground reaction force too far medial to the knee axis. Increased pressure will be exerted at the proximal medial and distal lateral portions of the residual limb. A pronated foot or a socket with too much lateral tilt will have the same effect. Conversely, the proximal lateral and distal medial areas will bear the brunt of a foot that is outset too far or supinated, or a socket set with too little lateral tilt. To summarize, the treatment for all of these conditions is modification of the prosthesis, addition or subtraction of socks, or use of methods to stabilize the volume of the limb. The last-named treatment may include the application of shrink socks, elastic stockinette, elastic bandages (ie, Ace wraps), elevation of the limb when it is not in the prosthesis, and wearing the prosthesis on a consistent basis.

Some patients simply possess fragile skin (ie, burns, skin grafts, adhesions). Gel liners of various thickness may be helpful. Urethane liners with multidirectional flow characteristics, ie, TEC™ liner,[b] may offer special advantages by distributing weight bearing more widely and more equally throughout the residuum.

Reaction to contact dermatitis runs the gamut from slight erythema to a fulminant reaction with local inflammation, vesiculation, crusting, and serious oozing. Although contact dermatitis can be exacerbated by pressure or shear, the history and the widespread distribution and character of the lesions are usually sufficient to distinguish this condition from those caused by mechanical forces alone. Treatment consists of removing offending agents—which usually means replacing the liner.

### 4.4 Objective: To evaluate the potential causes of recurrent knee buckling in a college coach with a transfemoral amputation.

Gait deviation in lower limb amputees can be caused by intrinsic (user-related) or extrinsic (prosthesis-related) factors or a combination of the 2. An adequate history and physical examination should be performed to detect any musculoskeletal, neurologic, dermatologic, cardiopulmonary, vascular, or rheumatologic factors that may cause weakness or pain, disturb sensation, or disrupt coordination or motor programming such that gait is impaired. The evaluation must also focus on the prosthesis itself and the user-prosthesis interface. Finally, the practitioner must be alert for psychologic factors that might cause rejection or sabotage of the prosthesis.

Most often, the amputee is first encountered in a seated position in the examination room. After the history has been obtained, the user is observed while doffing the prosthesis. Important information regarding the prosthetic fit and the user's attitude and comfort, familiarity, and facility with the prosthesis can be gleaned. Next, the residual limb is inspected for erythema, edema, rashes, abrasions, blisters, ulcerations, and other dermatologic abnormalities. This is followed by a palpatory examination to determine the condition of the soft tissue, the adherence of scar tissue, and the presence of focal or diffuse tenderness. The pattern of findings may suggest systemic or local disease, or problems with fit (ie, bottoming out or incomplete contact). Next, the examiner asks the user to don the prosthesis, noting any errors in technique. Static alignment and fit are evaluated while the user stands; dynamic alignment and fit are evaluated in the anteroposterior plane and the mediolateral plane while the user ambulates.

Typically, the user is assessed while he/she traverses a level surface. Depending on the history and the activity of the user, he/she may be asked to ascend and descend stairs or to run or walk on uneven terrain. The specific phase of gait in which the deviation occurs and the nature of the deviation are noted. A patient with a poorly fitting prosthesis may actually learn an adaptive gait pattern that allows relatively comfortable and efficient ambulation despite the shortcomings of the prosthesis. Careful analysis may reveal such compensatory strategies even if they are subtle.

One of the most common gait deviations in patients with transfemoral amputations is abrupt or excessive knee flexion during ambulation. This may result in dynamic instability, with recurrent knee buckling, loss of balance, and falls.[32] The prosthetic knee joint should normally be stable in extension in stance phase from heel contact to foot flat. This is accomplished in part by aligning the prosthetic knee axis posterior to the trochanteric-knee-ankle line, thus maintaining the knee in extension. Adequate strength and range of motion in hip extension are critical in maintaining this alignment. Thus, weak hip extensors and hip flexion contractures can cause knee instability. The prosthetic socket with an insufficient anterior-posterior diameter may cause undue and repetitive pressure on the hamstring tendons at the level of the ischial tuberosity. This can cause reduced hamstring function, with an increased ten-

dency for knee instability during stance phase, particularly at heel strike. Two prosthetic causes of knee instability are (1) knee axis malalignment in an excessively anterior position relative to the hip and ankle joints and (2) excessive socket flexion.

If the foot comes to foot flat prematurely, the knee axis may cross anterior to the trochanteric-knee-ankle line, again resulting in instability. This may be due to an overly firm prosthetic heel or a prosthetic heel inserted in a tight shoe, which limits compressibility of the heel. Other causes include a plantarflexion bumper that is too stiff excessive foot dorsiflexion, an overly long heel lever arm, a change in shoe heel height from low to high, and a socket with a too small anteroposterior diameter.[33] Careful static and dynamic gait analysis in a person with a lower limb deficiency, along with close inspection of the condition and alignment of the residual limb and prosthetic device, is essential in identifying and correcting gait deviations.

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*Key References.

### Suppliers

a. Conva Tec, PO Box 5254, Princteon, NJ 08543.
b. TEC Interface Systems, 820 Sundail Dr, Waite Park, MN 56387.